Human Autonomy Teaming Measures

Mike Matessa
Rockwell Collins

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Rockwell Collins

Building trust every day

Human-Autonomy Teaming

- How can autonomy best work with humans?
  - Have the qualities of a good team member
- How can these qualities be measured?
  - Use human teaming measures
  - Crew Resource Management

NOTECHS CRM

Category	Element	Behavior
Cooperation		
Management/ Leadership		
Situation Awareness		
Decision Making		

Flin et al. (2003)

NOTECHS CRM

Category	Element	Behavior
Cooperation	Considering others	Consider condition of other
	Supporting others	Offer assistance
Management/ Leadership		
Situation Awareness		
Decision Making		

Flin et al. (2003)

NOTECHS CRM

Category	Element	Behavior
Cooperation	Considering others	Consider condition of other
	Supporting others	Offer assistance
Management/ Leadership	Authority/Assertiveness	Take Initiative
	Maintain standards	Enforce SOP
	Planning/Co-ordinating	State plan
	Workload management	Distribute tasks
Situation Awareness		
Decision Making		

Flin et al. (2003)

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Situation Awareness	System awareness	Monitor/report system (incl. other crew)
	Env awareness	Monitor/report env
	Awareness of time (anticipation)	Monitor/report time constraints
Decision Making		

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Decision Making	Problem diagnosis	ID problem
	Option generation	Generate/elicit options
	Option selection	Select option
	Outcome review	Review outcome

Flin et al. (2003)

NATO Patterns

Human

Agent *(create own situation awareness, make decisions, plan course of action)*

Supervisory Relationship *(e.g., delegation)*

Cooperative Relationship *(e.g., assistance)*

NATO HFM-247 (2015)

Patterns + CRM

Human

Agent

Management: *Take initiative (Sheridan levels)*
SA: *Perceive, Comprehend, Project (Endsley levels)*
Decision Making: *ID problem, Generate options, Select option, Review outcome*

Patterns + CRM

Human

Agent

M1-10/S1-3/D1-4

Management: *Take initiative (Sheridan levels)*
SA: *Perceive, Comprehend, Project (Endsley levels)*
Decision Making: *ID problem, Generate options, Select option, Review outcome*

Patterns + CRM

Human

Agent

M1-10/S1-3/D1-4

Management: *Take initiative (Sheridan levels)*
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Decision Making: *ID problem, Generate options, Select option, Review outcome*

Supervisory Relationship
Management: *Command*
SA: *Monitor*

Patterns + CRM

Human

Agent

M1-10/S1-3/D1-4

Management: *Take initiative (Sheridan levels)*
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Decision Making: *ID problem, Generate options,*
Select option, Review outcome

M/S

Supervisory Relationship
Management: *Command*
SA: *Monitor*

Patterns + CRM

Human

Agent

M1-10/S1-3/D1-4

Management: *Take initiative (Sheridan levels)*
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Decision Making: *ID problem, Generate options, Select option, Review outcome*

M/S

Supervisory Relationship
    Management: *Command*
    SA: *Monitor*

Cooperative Relationship
    Cooperation: *Consider condition, Offer assistance*
    Management: *State Plan, Distribute tasks*
    SA: *Monitor/crosscheck*
    Decision Making: *Elicit options*

Patterns + CRM

Human

Agent

M1-10/S1-3/D1-4

Management: *Take initiative (Sheridan levels)*
SA: *Perceive, Comprehend, Project (Endsley levels)*
Decision Making: *ID problem, Generate options, Select option, Review outcome*

M/S

Supervisory Relationship
Management: *Command*
SA: *Monitor*

C/M/S/D

Cooperative Relationship
Cooperation: *Consider condition, Offer assistance*
Management: *State Plan, Distribute tasks*
SA: *Monitor/crosscheck*
Decision Making: *Elicit options*

Agent Measures

Situation Awareness (Endsley)
1) Perceive
2) Comprehend
3) Project

Agent Measures

Situation Awareness (Endsley)

1) Perceive

2) Comprehend

3) Project

Decision Making (NOTECHS)

1) ID problem

2) Generate options

3) Select option

4) Review outcome

Agent Measures

Situation Awareness (Endsley)

1) Perceive
2) Comprehend
3) Project

Decision Making (NOTECHS)

1) ID problem
2) Generate options
3) Select option
4) Review outcome

Management (Sheridan)

1 The computer offers no assistance: human must take all decision and actions.
2 The computer offers a complete set of decision/action alternatives, or
3 narrows the selection down to a few, or
4 suggests one alternative, and
5 executes that suggestion if the human approves, or
6 allows the human a restricted time to veto before automatic execution, or
7 executes automatically, then necessarily informs humans, and
8 informs the human only if asked, or
9 informs the human only if it, the computer, decides to.
10 The computer decides everything and acts autonomously, ignoring the human.

RCO Use Case

- **Initial Conditions.** Aircraft is enroute. There is one Pilot On Board and a dispatcher flight following, both assisted by autonomy.

- **Step 1. Detection and Alerting of Thunderstorm.**

- **Step 2. Dispatcher informs POB of cell.**

- **Step 3. Modification of Flight Plan.**

- **Step 4. Dispatch uplinks modified flight plan.**

- **Step 5. POB requests clearance for flight plan from ATC.**

- **Step 6. ATC rejects clearance.**

- **Step 7. Planning for Delay.**

- **Step 8. POB requests clearance from ATC**.

- **Step 9. POB tells Agent to implement the new clearance.**

From Shively et al. (2016)

RCO Pattern

Supervisory Relationship

Cooperative Relationship

Aircraft

Dispatch

ATC
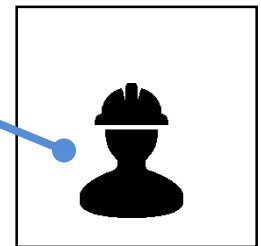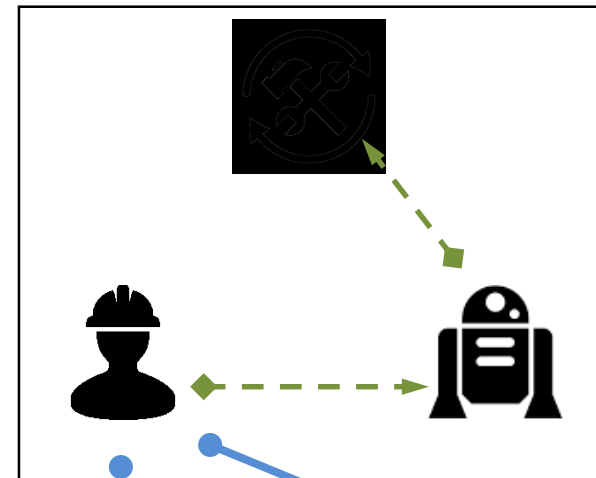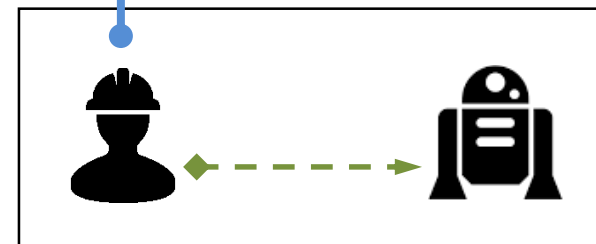
From Shively et al. (2016)

RCO Measures

Management
Command

Aircraft

M

M

ATC

M
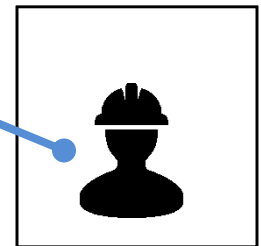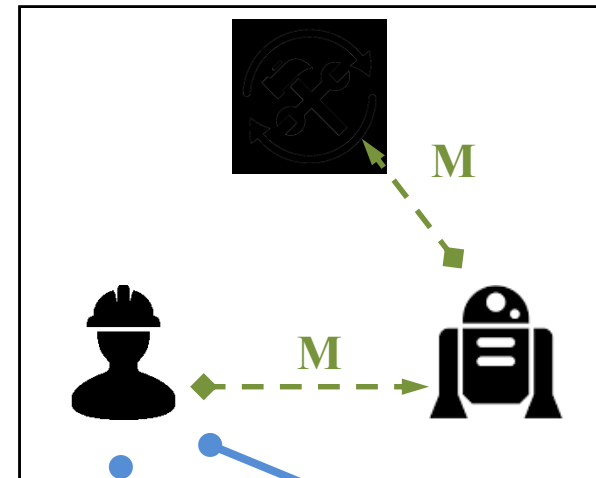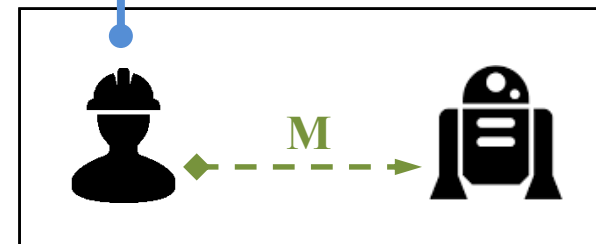
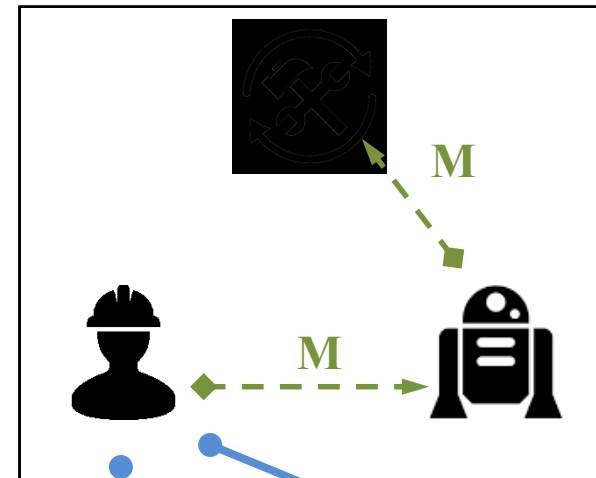**Dispatch**

RCO Measures

Cooperation:
Consider condition of other

Management:
Distribute tasks

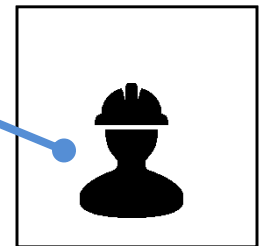**Situation Awareness:**
Monitoring other
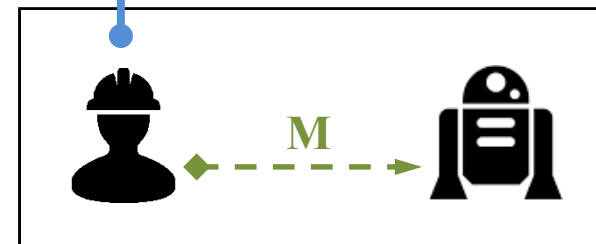
Decision Making:
Elicit options

Aircraft

M

M

C/M/S/D

C/M/S/D

ATC
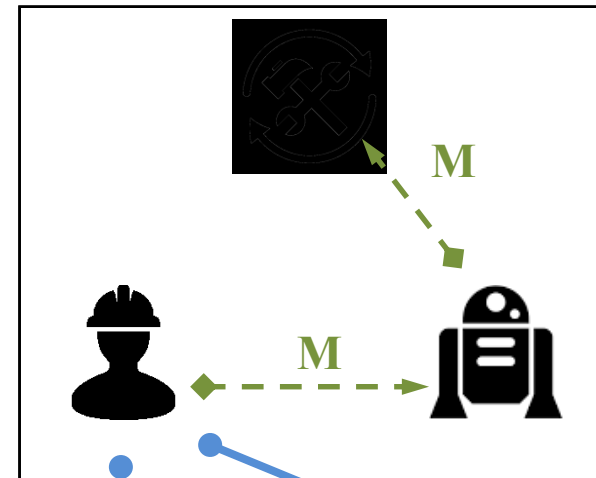
Dispatch

M

RCO Measures

Decision Making
3) Select option

Aircraft
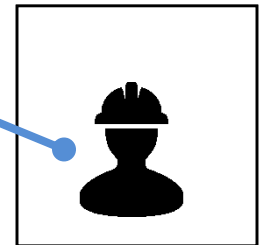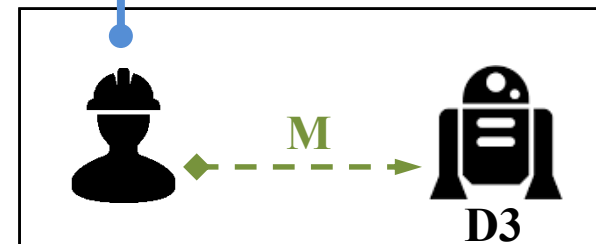
M

M

C/M/S/D

C/M/S/D

ATC

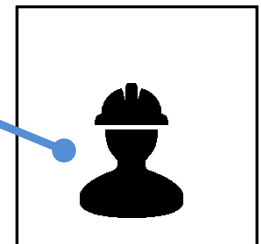**Dispatch**

D3

M

RCO Measures
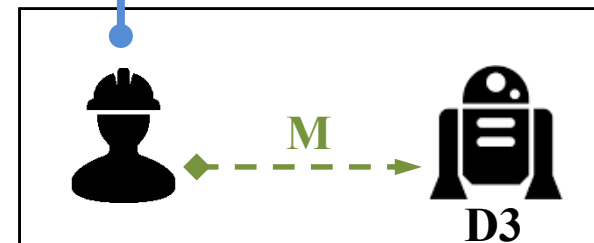
Situation Awareness
3) Project

Decision Making
2) Generate options
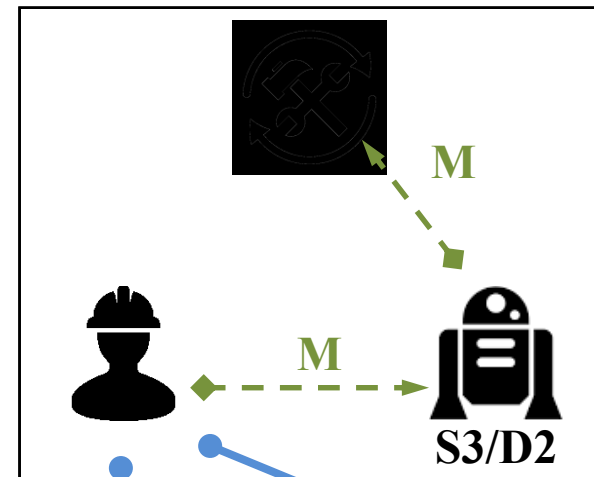
Auto TCAS Use Case

- **Initial Conditions.** RCO with onboard Auto TCAS Agent
- **Step 1.** Agent detects traffic and provides avoidance option
- **Step 2.** POB does not react in time
- **Step 3.** Agent implements option

Auto TCAS Measures

Management
Command

Situation Awareness
Monitor
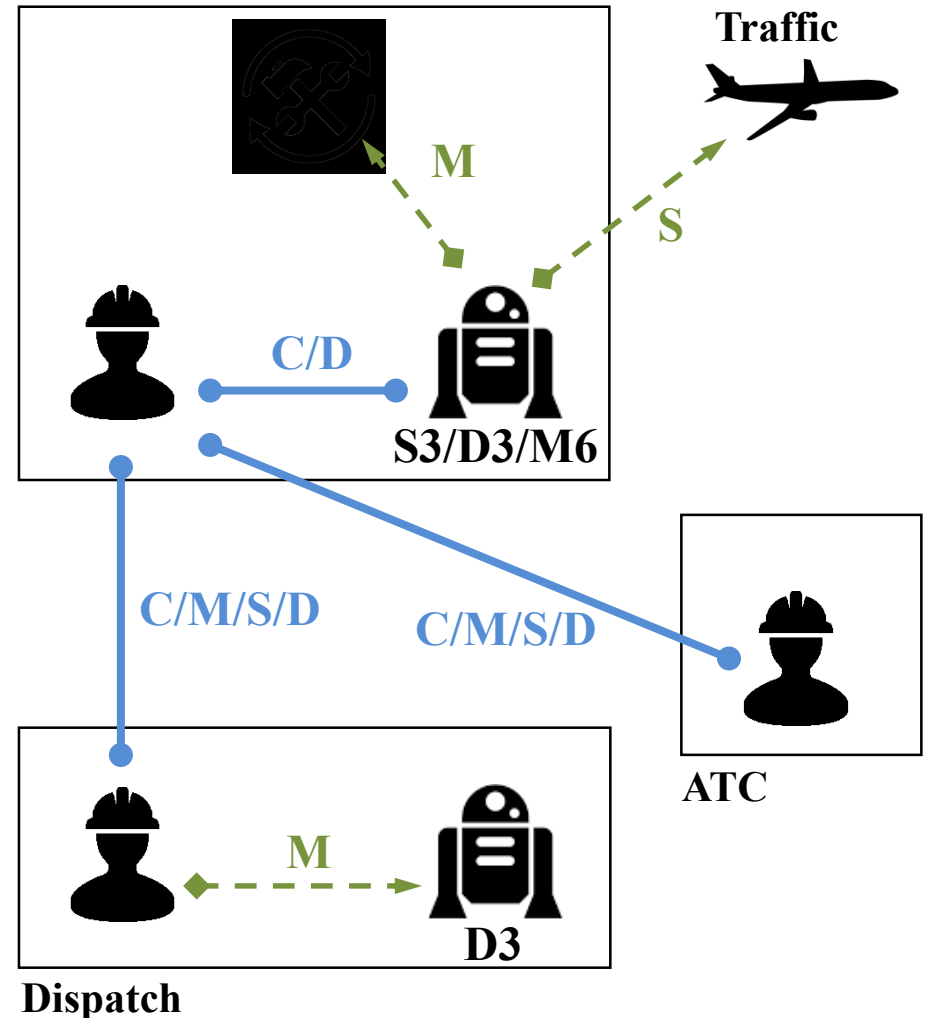
Cooperation:
Consider condition of other

Decision Making:
Elicit options

Situation Awareness
3) Project

Decision Making
3) Select option

Management
6) allows the human a restricted time to veto before automatic execution

Aircraft

Traffic

M

S

C/D

S3/D3/M6

C/M/S/D

C/M/S/D

ATC

Dispatch

M

D3

RCO Measures
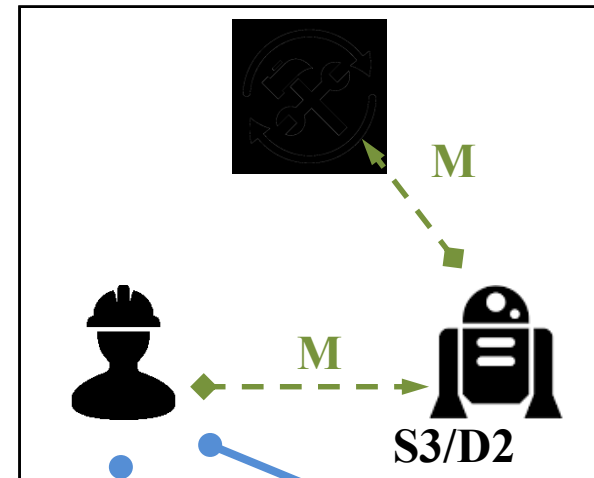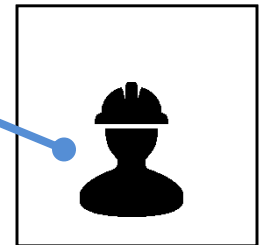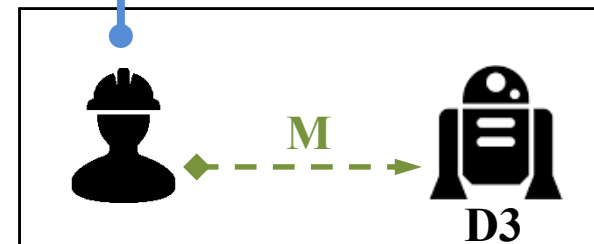
NASA UAS Ground Station
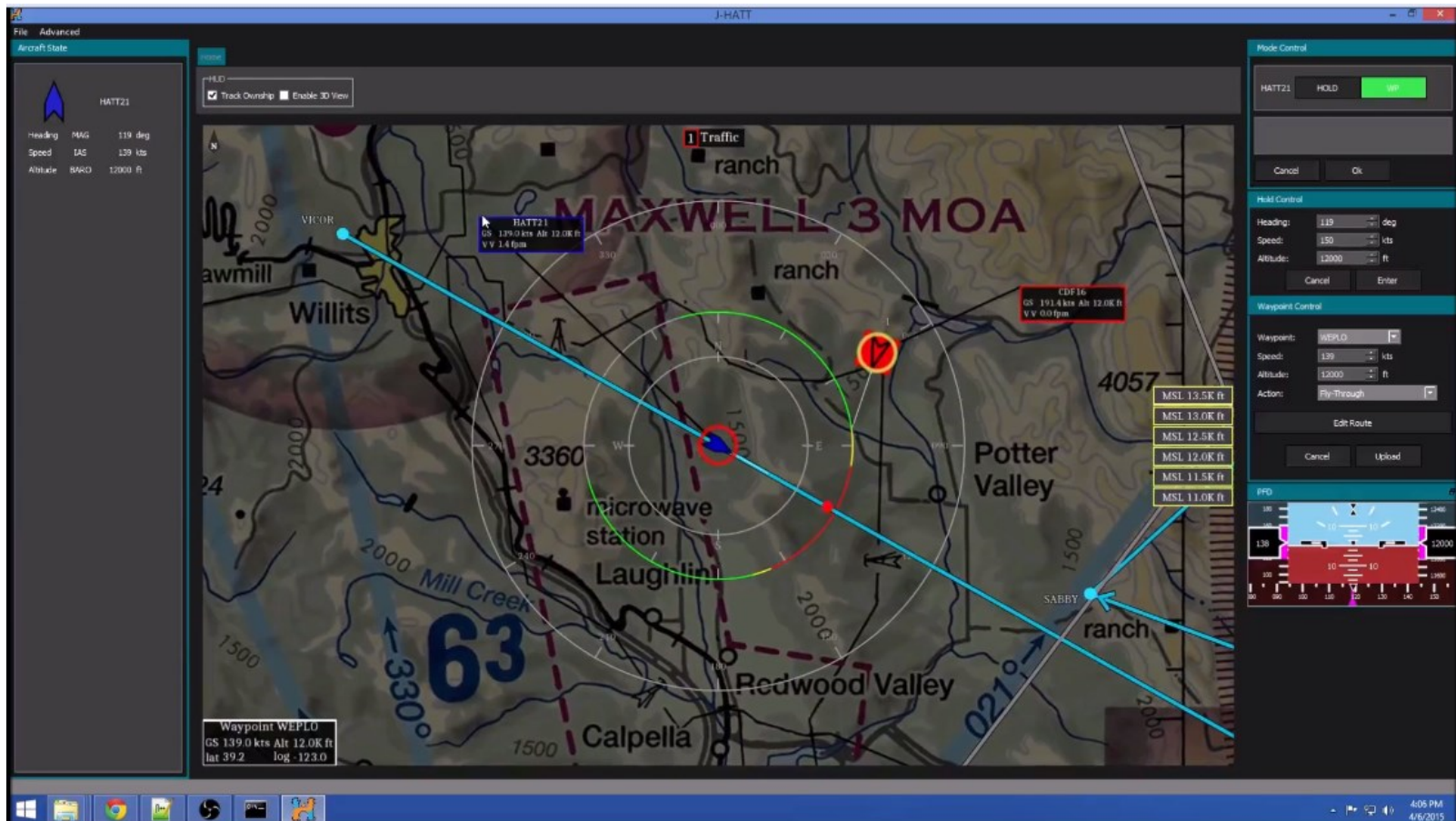
UAS Evaluation

Management
Command
Situation Awareness
Monitor

Situation Awareness
3) Project

Management
3) narrows the selection of options down to a few

Decision Making
2) Generate options

UAS

Traffic

S3/M3/D2

S

M/S

Operator
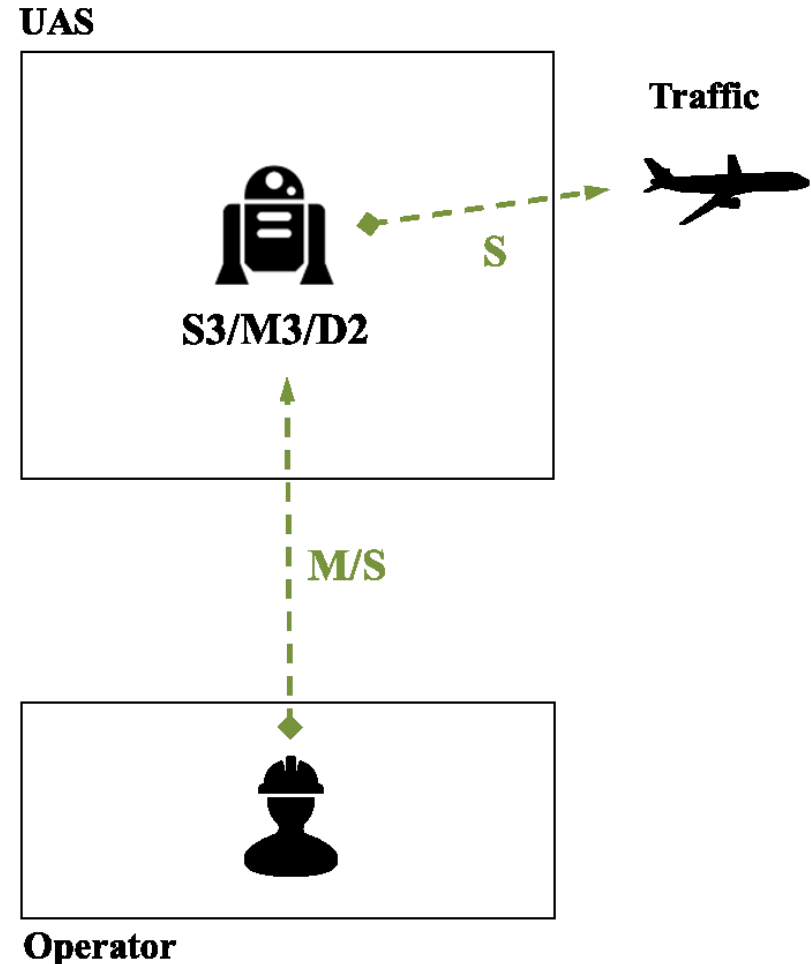
UAS detects conflict and provides avoidance arc

Agent and Relationship Measures

M1-10/S1-3/D1-4

Agent

Management: *Take initiative (Sheridan levels)*
SA: *Perceive, Comprehend, Project (Endsley levels)*
Decision Making: *ID problem, Generate options, Select option, Review outcome*

M/S

Supervisory Relationship
Management: *Command*
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C/M/S/D

Cooperative Relationship
Cooperation: *Consider condition, Offer assistance*
Management: *State Plan, Distribute tasks*
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Decision Making: *Elicit options*

Agent Measures

Situation Awareness (Endsley)
1) Perceive
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3) Project

Decision Making (NOTECHS)
1) ID problem
2) Generate options
3) Select option
4) Review outcome

Management (Sheridan)

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   autonomously, ignoring the human.

Agent Measures

Category	Element	Behavior	
Cooperation	Considering others	Consider condition of other	
	Supporting others	Offer assistance	
Management/ Leadership	Authority/Assertiveness	Take Initiative	**M1-10**
	Maintain standards	Enforce SOP	
	Planning/Co-ordinating	State plan	
	Workload management	Distribute tasks	
Situation Awareness	System awareness	Monitor/report system (incl. other crew)	**S1-3**
	Env awareness	Monitor/report env	
	Awareness of time (anticipation)	Monitor/report time constraints	
Decision Making	Problem diagnosis	ID problem	**D1-4**
	Option generation	Generate/elicit options	
	Option selection	Select option	
	Outcome review	Review outcome	

Relationship Measures

Category	Element	Behavior	
Cooperation	Considering others	Consider condition of other	**C**
	Supporting others	Offer assistance	
Management/ Leadership	Authority/Assertiveness	Take Initiative	**M**
	Maintain standards	Enforce SOP	
	Planning/Co-ordinating	State plan	
	Workload management	Distribute tasks	
Situation Awareness	System awareness	Monitor/report system (incl. other crew)	**S**
	Env awareness	Monitor/report env	
	Awareness of time (anticipation)	Monitor/report time constraints	
Decision Making	Problem diagnosis	ID problem	**D**
	Option generation	Generate/elicit options	
	Option selection	Select option	
	Outcome review	Review outcome	

HAT Measure Benefits

- ## System Design
  - Use measure categories to ensure coverage of teaming behavior

- ## Scenario Development
  - Use behavioral markers of measures to develop scenarios to elicit performance

- ## System Evaluation
  - Use behavioral markers to test performance

Next Steps

- Apply measures to more use cases

- Use measures to drive improvements to NASA autonomy projects

QUESTIONS?

Cooperation

Element	Good practice	Poor practice
Team building and maintaining	Establishes atmosphere for open communication	Blocks open communication
	Encourages inputs and feedback from others	Keeps barriers between crewmembers (CM)
	Does not compete with others	Competes with others
Considering others	Takes notice of the suggestions of other CM even if s/he does not agree	Ignores suggestions of other CM
	Takes condition of other CM into account	Does not take account of the condition of other CM
	Gives personal feedback	Shows no reaction to other CM
Supporting others	Helps other CM in demanding situations	Hesitates to help other CM in demanding situations
	Offers assistance	Does not offer assistance
Conflict solving	Keeps calm in interpersonal conflicts	Overreacts in interpersonal conflicts
	Suggests conflict solutions	Sticks to own position without considering a compromise
	Concentrates on what is right rather than who is wrong	Accuses other CM of making errors

Situation Awareness

Perception (Level 1 SA): The first step in achieving SA is to perceive the status, attributes, and dynamics of relevant elements in the environment. Thus, Level 1 SA, the most basic level of SA, involves the processes of monitoring, cue detection, and simple recognition, which lead to an awareness of multiple situational elements (objects, events, people, systems, environmental factors) and their current states (locations, conditions, modes, actions).

Comprehension (Level 2 SA): The next step in SA formation involves a synthesis of disjointed Level 1 SA elements through the processes of pattern recognition, interpretation, and evaluation. Level 2 SA requires integrating this information to understand how it will impact upon the individual's goals and objectives. This includes developing a comprehensive picture of the world, or of that portion of the world of concern to the individual.

Projection (Level 3 SA): The third and highest level of SA involves the ability to project the future actions of the elements in the environment. Level 3 SA is achieved through knowledge of the status and dynamics of the elements and comprehension of the situation (Levels 1 and 2 SA), and then extrapolating this information forward in time to determine how it will affect future states of the operational environment.

Behavioral Markers

- The term behavioral markers refers to a prescribed set of behaviors indicative of some aspect of performance (Flin & Martin, 2001)

RCO Use Case

- **Initial Conditions.** FLYSKY12 is en route from SFO to ORD. There is one POB and a dispatcher flight following.

- **Step 1. Detection and Alerting of Thunderstorm.** Dispatch automation informs dispatcher of convective cell growing on flight path of FLYSKY12.

- **Step 2. Dispatcher informs POB of cell. Step 3. Modification of Flight Plan.** Seeing a need to re-route, the dispatcher requests modified flight plan from dispatch automation. Dispatch automation returns modified flight plan.

- **Step 4. Dispatch uplinks modified flight plan.**

- **Step 5. POB requests clearance for flight plan from ATC.**

- **Step 6. ATC rejects clearance.** ATC tells POB that aircraft must take additional six-minute delay for new arrival slot coming into ORD.

- **Step 7. Planning for Delay.** POB asks automation for alternatives to take six-minute delay. Automation provides two alternatives: a) Slow down, saves fuel but risks further movement/growth of cell b) Hold past cell, more fuel burn but lower risk of further deviations.

- **Step 8. POB requests clearance from ATC**. Modified with holding after passing cell; ATC approves request.

- **Step 9. POB tells Agent to implement the new clearance.** Agent sets autopilot in accord with